Science Letters ISSN 2345-5463
DOI: https://doi.org/10.47262/SL/10.3.132022400

Research article
2022 | Volume 10 | Issue 3 | Pages 115-120

ARTICLE INFO

Received
August 23, 2022
Revised
November 03, 2022
Accepted
November 05, 2022
Published
December 20, 2022

***Corresponding author**
Muhammad Asif
Email
drasifpk@gmail.com

Keywords
Cucumber
Drip irrigation
Deficit irrigation
Greenhouse
Fertilizer
Water productivity

How to cite
Anjum MS, Datta A, Asif M, Rafique MA. Effects of deficit irrigation and fertigation on growth, yield and water productivity of greenhouse-grown cucumber. Sci Lett 2022; 10(3):115-120

SCAN ME

Open Access

Effects of Deficit Irrigation and Fertigation on Growth, Yield and Water Productivity of Greenhouse-Grown Cucumber

Muhammad Sadiq Anjum[1], Avishek Datta[1], Muhammad Asif[2]*, Muhammad Asim Rafique[2]

[1]Department of Food, Agriculture and Bioresources, School of Environment, Resources and Development, Asian Institute of Technology, Pathum Thani, Thailand
[2]Directorate of Agriculture, On Farm Water Management, 25000, Faisalabad, Punjab, Pakistan

Abstract

Low water productivity has caused the wastage of water in agricultural production. Water productivity can be increased by using drip irrigation for vegetables on raised beds in greenhouses. For this purpose, a greenhouse study was conducted on sandy loam soil at the Experimental Research Station of the Asian Institute of Technology, Thailand. The experiment was designed in randomized complete block design having ten treatments using three irrigation levels [100%, 80%, 60% of actual evapotranspiration (ET_c)] and three recommended dose of fertilizer (RDF) levels [100%, 80%, 60%]. Furrow irrigation with 100% of RDF was used as a control treatment. Data of crop and water productivity were recorded; the results showed that treatment T_5 ($W_{80\%ETc}$ $F_{80\%RDF}$) under deficit irrigation and fertigation recorded the highest mean fresh fruit yield of 66.71 t/ha while the full irrigation treatments T1 ($W_{100\%\ ETc}$ $F_{100\%\ RDF}$) and T_2 ($W_{100\%ETc}$ $F_{80\%RDF}$) recorded the lowest mean fresh fruit yield of 12.9 t/ha and 13.9 t/ha, respectively, as against 9.6 t/ha for the control plot. Also, T_5 recorded the highest water productivity of 14.47 kg/m^3 while full irrigation treatments (T_1 and T_2) recorded the lowest water productivity of 2.52 kg/m^3 and 2.73kg/m^3, respectively, as against 1.37 kg/m^3 for the control plot. A deficit irrigation level of 80% of ET_c with a fertilizer level of 80% of RDF was found most suitable for sandy loam soil to improve crop growth, yield and water productivity for greenhouse-grown cucumber under the drip irrigation system. The results also suggest that a 20% deficit irrigation and fertilizer approach may be a good strategy for increasing water productivity when full irrigation is not possible due to limited water supplies.

Introduction

In Pakistan, a 0.22 million hectare area is cultivated for vegetables with an annual production of 0.94 million tons. It is estimated that, by 2025, the vegetable demand of the country would be around 135 million tons [1]. To achieve this target, attention must be focused on vertical expansion, strengthened with the boom of technology instead of horizontal expansion just by increasing the crop area [2]. Govt. of Pakistan is promoting drip irrigation and greenhouse technology for vegetable crops [3, 4]. Drip irrigation with its ability of small and frequent application of water has created interest among farmers because of less water requirement, increased production and better-quality produce. An economic evaluation of drip irrigation in fruit crops (vegetables, orchards) in Punjab reveals that this system conserves a considerable amount of water and results in better returns despite higher initial investment [5].

The cucumber (*Cucumis sativus* L.) is an important vegetable crop in Pakistan. It is richer in vitamins than tomatoes, especially vitamins A and C [6]. It is a hot season crop and can be grown the whole year mainly in the greenhouse. It grows better under high temperatures, relative humidity and a continuous supply of nutrients [7]. The production of this crop is affected adversely by moisture deficit. Productivity of the crop can be increased by adopting an improved package of practices, particularly *in-situ* moisture conservation by mulching as well as high-tech irrigation especially drip irrigation with appropriate irrigation scheduling [8]. The application of a deficit amount of water combined with fertilizers through a drip irrigation system will be a suitable approach to maximize crop and water productivity of greenhouse cucumbers in Punjab, Pakistan. Numerous experiments have reported the benefits of deficit irrigation and fertigation in several crops [9, 10], but the research is limited on the response of deficit irrigation and fertigation for cucumber production. Keeping this in the background, the present study was undertaken to evaluate the effect of deficit irrigation and fertigation on cucumber under a drip irrigation system and compare the results with conventional furrow irrigation. Further, this research was carried out to study the effect of deficit irrigation and fertigation to attain efficient water utilization and saving without affecting crop yield or quality and to quantify the amount of irrigation water and fertilizers required for greenhouse-grown cucumber sown under a plastic tunnel with drip irrigation.

Materials and Methods

The study was conducted from December 2019 to March 2020 at the Experimental Research Station of the Asian Institute of Technology, Thailand. The geographical location of the site is latitude 14º 04′ N and longitude 100º 37′E. The climate of the study area is classified as tropical with an average temperature of 28.1°C and an average precipitation of 1426 mm. The overall experimental area was 200 m^2 (10m × 20m) with 30 equal blocks and each of the blocks had an area dimension of 3m^2 (1.5m × 2m). The experimental design was the randomized complete block design (RCBD) replicated thrice. Normal cultivation practices involved in cucumber production were observed. Minja (Chia Thai) cucumber variety was sown directly into the soil on December 4, 2018, in the greenhouse and at the maturity stage, the plants were supported vertically with the help of a plastic net. NPK (15:15:15) was used as basal dose, and urea (46-0-0) was also applied for the development of plants according to the crop growth stage requirement. The treatments include three irrigation levels of 100%, 80% and 60% of crop water requirement (ETc) and three fertilizer levels of 100%, 80% and 60% of the recommended dose of fertilizer (RDF). In detail, treatments comprised of T1 = $W_{100\%ETc}\,F_{100\%RDF}$, T2 = $W_{100\%ETc}\,F_{80\%RDF}$, T3 = $W_{100\%ETc}\,F_{60\%RDF}$, T4 = $W_{80\%ETc}\,F_{100\%RDF}$, T5 = $W_{80\%ETc}\,F_{80\%RDF}$, T6 = $W_{80\%ETc}\,F_{60\%RDF}$, T7 = $W_{60\%ETc}\,F_{100\%RDF}$, T8= $W_{60\%ETc}\,F_{80\%RDF}$, T9 = $W_{60\%ETc}\,F_{60\%RDF}$ and T10 = Furrow $F_{100\%}$ (control). The Linear low-density polyethylene (LLDPE) film of 50-micron thickness was used for mulching around the plant. The lateral lines of 12 mm diameter LLDPE pipes were laid along the crop rows and each lateral served two rows of crop. The laterals were provided with a line dripper of 2.40 liter per hour (LPH) discharge capacity. LLDPE pipes of 75 mm diameter were used for the main and 63 mm diameter was used for the sub-main. The main line was directly connected to a 1.5 HP pump installed to lift water from an open sump. The manifold unit was connected with a screen filter, a pressure gauge and a control valve. The duration of delivery of water to each treatment was controlled with the help of gate valves provided at the inlet end of each lateral. In the case of surface irrigation, irrigation was scheduled weekly. CROPWAT

model [11] was used for the crop water requirement of greenhouse-grown cucumber for the growing season.

The reference crop evapotranspiration (ET_o) for the cucumber growth period was calculated with the Penman-Monteith equation [12].

$Et_{c.} = K_c \times ET_o$

Where ET_c is actual crop evapotranspiration (mm/day), K_c is crop coefficient and ET_o is reference evapotranspiration in (mm/day)

Water productivity was determined by dividing the yield to seasonal evapotranspiration and total irrigation water applied and calculated by the following equation:

Water productivity = Actual yield (kg/m^2) / total volume of water for season (m^3/m^2)

Where water productivity (kg/m^3), actual yield (kg/m^2), ET_c is seasonal crop evapotranspiration (m^3/m^2).

Actual yield collected (kg/m^2) from each replication respective area ($3m^2$) and then was determined for each treatment area ($9m^2$). Analysis of variance (ANOVA) for the experiment was taken and the difference between the means was determined using Least Significant Difference (LSD) [13].

Results and Discussion

Growth and yield attributes

The data of yield and yield attributing characters like no. of fruits/plant, fruit length and fruit weight are presented in Table 1. The results revealed that yield and yield attributing characters were significantly superior in treatment T5 than in other treatments. The deficit irrigation and fertigation had a significant effect on the fruit set. The minimum fruit setting days were recorded 29 days after sowing (DAS) under treatment T5 ($W_{80\%ETc}$ $F_{80\%RDF}$) and 30 DAS under treatments T6 ($W_{80\% ETc}$ $F_{60\% RDF}$) and T9 ($W_{60\% ETc}$ $F_{60\% RDF}$). While 34, 33 and 33 DAS fruit-setting days were observed under full irrigation treatments T1, T2 and T10, respectively. The results obtained were in agreement with that of Arshad [14]. The time taken to fruit maturity was positively affected by deficit levels of irrigation and fertigation. The minimum number of days (48 DAS) were counted for fruit maturity for treatment T5, followed by T9 (51 DAS) and T6 (52 DAS), respectively. Overall, fruit maturity days decreased with the decrease in fertilizer under both full and deficit irrigation. The number of fruits per plant was increased in treatment T5 (394.4%) followed by T7 (205.6%) compared to the control treatment. The results revealed that the number of fruits per plant were decreased by 55.6% for treatment T2, because of more vegetative growth as compared to fruit development under full irrigation while the number of fruits per plant were increased with a decrease of fertilizer under deficit irrigation. Similarly, deficit irrigation and fertigation have a positive effect on the fruit weight of cucumber as the fruit concentrates to increase the weight instead of growing under deficit nutrients. Treatment T9 showed maximum fruit weight per plant (449 g) followed by T6 (440 g) and T5 (439 g), while the minimum fruit weight (217 g) was recorded in treatment T10 followed by T7 (293 g), T1 (301.26 g) and T_3 (327 g), respectively. The response of

Table 1 Growth and yield of greenhouse cucumber, as influenced by different levels of irrigation and fertilizer.

Treatments	Days to fruit setting	Days to fruit maturity	Fruits/plant	Fruit length (cm)	Fruit dia. (cm)	Fruit weight (g)	Yield (t/ha)
$T_1 = W_{100\%ETc} F_{100\%RDF}$	34a	59.3 ab	1.0 h	15.3 c	3.5 g	301.3 i	12.9 e
$T_2 = W_{100\% ETc} F_{80\% RDF}$	33 a	60.7 a	0.8 i	15.6 bc	4.5 d	344.5 e	13.7e
$T_3 = W_{100\% ETc} F_{60\% RDF}$	32 b	62.0 a	3.0 e	17.6 b	4.9 c	326.8 f	21.3 d
$T_4 = W_{80\% ETc} F_{100\% RDF}$	31 b	52.7 cd	4.9 c	20.5 a	5.6 b	416.8 d	40.8 b
$T_5 = W_{80\% ETc} F_{80\% RDF}$	29 a	48.0 e	8.9 a	21.7 a	5.6 b	439.2 b	66.7 a
$T_6 = W_{80\% ETc} F_{60\% RDF}$	30 b	52.3 cde	4.9 c	20.8 a	5.6 b	440.1 b	39.1 c
$T_7 = W_{60\% ETc} F_{100\% RDF}$	31 c	52.7 cd	5.5 b	15.5 bc	4.2 e	293.1 h	40.1 b
$T_8 = W_{60\% ETc} F_{80\% RDF}$	31 c	58.0 ab	2.6 f	20.3 a	5.8 a	431.1 c	20.5 d
$T_9 = W_{60\% ETc} F_{60\% RDF}$	30 b	51.0 de	3.5 d	21.8 a	5.8 a	448.9 a	27.9 d
T_{10} = Furrow $F_{100\% RDF}$	33 a	56.0 bc	1.8 g	16.7 bc	3.9 f	217.1 g	9.6 f
Pr (>F)	0.00**	0.00**	0.00**	0.00**	0.000**	0.00**	0.00**
CV (%)	0.4	2.7	0.3	4.2	0.39	0.6	0.5
SE	0.02	1.23	0.01	0.63	0.02	1.91	0.12

Asterisks '*' and '**' indicate significance at p<0.05 and p<0.01 probability level, respectively.
W = water level of crop water requirement (Etc); F = fertilizer level of the recommended dose of fertilizer (RDF); dia. = diameter; CV = confidence of interval; SE = standard error

Table 2 Water productivity (WP) of cucumber, as influenced by different levels of irrigation and fertilizer.

Treatments	Yield (kg/ha)	Volume of water applied (m^3)	Volume of water (m^3/ha)	WP (kg/m^3)
$T_1 = W_{100\%ETc} F_{100\%RDF}$	13673.3	1.50	5000.0	2.52h
$T_2 = W_{100\% ETc} F_{80\% RDF}$	12940.0	1.54	5133.3	2.73g
$T_3 = W_{100\% ETc} F_{60\% RDF}$	21387.8	1.49	4966.7	4.32 f
$T_4 = W_{80\% ETc} F_{100\% RDF}$	40841.8	1.44	4800.0	8.54 c
$T_5 = W_{80\% ETc} F_{80\% RDF}$	66711.9	1.38	4600.0	14.47 a
$T_6 = W_{80\% ETc} F_{60\% RDF}$	39173.3	1.4	4666.7	8.39 c
$T_7 = W_{60\% ETc} F_{100\% RDF}$	40133.7	1.28	4266.7	9.41 b
$T_8 = W_{60\% ETc} F_{80\% RDF}$	20570.7	1.30	4333.3	4.76 e
$T_9 = W_{60\% ETc} F_{60\% RDF}$	27970.4	1.33	4433.3	6.32 d
T_{10} = Furrow $F_{100\% RDF}$	9647.0	2.10	7000.0	1.37 gh
Pr(>F)				0.00**
CV (%)				2.3
SE				0.12

Asterisk '**' indicates significance at $P<0.05$ probability level.
W = water level of crop water requirement (Etc); F = fertilizer level of the recommended dose of fertilizer (RDF); CV = confidence of interval; SE = standard error

cucumber to drip irrigation in terms of fruit weight improvement was found to be different in different agro-climatic and soil conditions [15]. The increased yield and growth attributes under T5 might be due to the supply of water and nutrients in adequate proportion, which resulted in triggering the production of plant growth hormones like indole acetic acid (IAA) and a higher number of leaves throughout the cropping period [16]. In another study, the deficit irrigation and fertilizer through drip irrigation significantly increased the yield of capsicum compared to full irrigation [17]. In this study, among various treatments, the highest yield (66.71 t/ha) was recorded under treatment T5 ($W_{80\%ETc} F_{80\%RDF}$), which was an 85% increase over T2 ($W_{100\%ETc} F_{80\%RDF}$) and an 80% increase over T1 ($W_{100\%ETc} F_{100\% RDF}$). The results further revealed that the yield was improved with deficit irrigation up to ETc 80%, while it was reduced drastically under full irrigation and irrigation level of 60% ETc. The lower yield obtained under the surface irrigation method (9.6 t/ha) might be due to water stress during the critical growth period, coupled with aeration problems in the first few days immediately after irrigation and less availability of nutrients for crop growth due to leaching with over-irrigation [18].

Water productivity

The water productivity of cucumber was highly dependent on soil, variety, weather conditions and method of water and fertilizer management. The drip irrigation method proved to be very beneficial for higher water saving. Water productivity (yield per unit area per unit depth of water used) was decreased with full irrigation treatments (T1, T2, and T3) where the water application was 100% of ET_c, while it improved with the decrease of irrigation level. A similar trend has been reported for water use efficiency for okra by Hashed et al. [18] and for tomatoes by Pattanaik et al. [19]. The maximum water productivity (14.47 kg/m^3) was measured for treatment T5, while the minimum water productivity (1.37 kg/m^3) was recorded in control treatment T10 followed by treatment T1 (2.73 kg/m^3) and T2 (2.52 kg/m^3), respectively. However, the combined effect of water and fertilizer was found highly significant under Treatment T5 ($W_{80\%ETc} F_{80\%RDF}$). The lowest water productivity obtained in T10 (flood irrigation) might be due to over-irrigation that resulted in nutrient leaching below the root zone, so ultimately yield was reduced and water resources were wasted. A similar study was conducted by Pattanik et al. [19] and concluded that water productivity increased under deficit irrigation. Patanè et al. [20] and Kirda et al. [21] also conducted similar experiments and found maximum water productivity (18.22 kg/m^3) with deficit irrigation and fertigation. In this study, the total applied water volume from sowing to harvesting was measured and recorded from the installed flow meter on each sub-main line and water productivity was obtained maximum (14.47 kg/m^3) for treatment T5 ($W_{80\%ETc} F_{80\%RDF}$), but it was lower compared to other studies due to no use of mulching, high temperature and deep percolation at the experimental site. Contrarily, El-Mageed et al. [15] reported highest

Table 3 Water saving with respect to control treatment under different levels of irrigation and fertilizer.

Treatments	Total volume of water applied (m^3)	Average volume of water applied (m^3)	Water saved (%)
$T_1 = W_{100\%ETc} F_{100\%RDF}$	4.51	1.50	40.00e
$T_2 = W_{100\% ETc} F_{80\% RDF}$	4.63	1.54	36.36c
$T_3 = W_{100\% ETc} F_{60\% RDF}$	4.46	1.49	40.94c
$T_4 = W_{80\% ETc} F_{100\% RDF}$	4.31	1.44	45.83c
$T_5 = W_{80\% ETc} F_{80\% RDF}$	4.15	1.38	52.17b
$T_6 = W_{80\% ETc} F_{60\% RDF}$	4.20	1.4	50.00b
$T_7 = W_{60\% ETc} F_{100\% RDF}$	3.84	1.28	64.06a
$T_8 = W_{60\% ETc} F_{80\% RDF}$	3.89	1.30	61.54a
$T_9 = W_{60\% ETc} F_{60\% RDF}$	3.98	1.33	57.89a
T_{10} = Furrow $F_{100\% RDF}$	6.30	2.10	
Pr (>F)	0.00**	0.00**	0.00**
CV (%)	0.4	2.7	0.3
SE	0.02	1.23	0.01

Asterisk '**' indicates significance at $p<0.01$ probability level, respectively.
W = water level of crop water requirement (Etc); F = fertilizer level of the recommended dose of fertilizer (RDF); CV = confidence of interval; SE = standard error

average cucumber fruit yield with maximum water productivity of 18.22 kg/m^3 obtained with full irrigation treatment using the drip irrigation method. However, several previous reports stated that the application of excessive irrigation water did not increase grain yields [22-24].

Water saving

The water saving under different treatments was compared with the control treatment/farming practice (Table 3). The results showed that the average reduction in irrigation water use (or water saving) for drip irrigation treatments T7, T8 and T9 compared with control were 64%, 62% and 59%, respectively. The average total volume of applied water was 6.3m^3, which is almost 20% more than that of full irrigation treatments (T1 and T2) and control plot. Although, maximum water was saved under the irrigation level of $60\%_{ETc}$ as against water level of $80\%_{ETc}$ and $100\%_{ETc}$ and control plot. However, treatment T5 ($W_{80\%ETc}$ $F_{80\%RDF}$), exhibited higher fresh fruit yield with water saving of almost 52% as compared to control treatment. Similar results have been reported by Houshang et al. [26]. From the point view of saving limited water resources in a semi-arid area, the results show the benefits of seasonal irrigation using a simple high efficiency irrigation system such as drip irrigation compared with conventional furrow irrigation at 8-day intervals, currently used by local farmers and predicted by CROPWAT modeling.

Conclusions

This study evaluated the effect of deficit irrigation and fertigation on growth, yield and water productivity of greenhouse-grown cucumber at different irrigation and fertilizer levels under drip irrigation. Increased water amounts resulted in lower crop and water productivity since water deficit was the main yield-limiting factor. These findings supported the hypothesis that best crop growth occurs when soil moisture remains within filed capacity and over-irrigation would produce less yield due to leaching of soil nutrients and poor aeration in the root zone. The seasonal water applied and grain yield of cucumber exhibited strong quadratic relationships. In this study, higher values of both crop yield and water productivity were obtained when irrigation was scheduled at 80 percent of ETc and 80% fertilizer of recommended dose. On the other hand, full irrigation (100% of ETc) gave the lowest yield both under drip irrigation and furrow irrigation. Finally, the overall results clearly revealed that in order to obtain higher yield, 20% deficit irrigation of ETc and 20% less fertilizer of RDF under drip irrigation may be a good strategy for improving water productivity with scarce water resources.

Acknowledgement

The authors are thankful to advisor Dr. Avishek Datta, Professor, Department of Food, Agriculture and Bioresources, School of Environment, Resources and Development, Asian Institute of Technology Thailand, for supervising and supporting this research for M.Sc. Thesis. The authors are also highly grateful to Dr. Muhammad Asif, Director Agriculture, and Mr. Asim Rafique Deputy Director Agriculture, On Farm Water Management, Faisalabad, Punjab, Pakistan who

gave insight and knowledge that considerably aided the research.

Conflict of interest

The authors claim no conflicts of interest.

References

1. GOP. Pakistan Economy Survey. Govt. of Pakistan, Finance Division, Economic Advisor's Wing, Islamabad, Pakistan: 2016-17.
2. Ali M. Ali L, Sattar M, Ali MA. Response of seed cotton yield to various plant populations and planting methods. J Agric.Res 2010; 48:163-169.
3. Akram MM, Asif M, Rasheed S, Rafique MA. Effect of drip and furrow irrigation on yield, water productivity and economics of potato (*Solanum tuberosum* L.) grown under semiarid conditions. Sci Lett 2020; 8(2):48-54.
4. Asif M, Rafique MA, Rindhwa AZ. Water productivity and economic profitability of maize plantation on raised beds under drip irrigation and conventional ridge planting. Sci Lett 2022; 10(3):109-114.
5. Randhawa NS, Abrol IP. Sustaining agriculture: the Indian scene, In: Sustainable Agriculture Systems, Edwards CA, Lal R, Madden P, Miller RH, House G. (eds.). Soil and Water Conservation Society, Ankeny, Iowa, USA; 1990, pp. 438- 450.
6. Sahin U, Kuslu Y, Kiziloglu FM. The response of cucumbers to different irrigation regimes applied through the drip irrigation system. J Anim Plant Sci 2015; 25(1):198-205.
7. Stanghellini C, Kempkes FLK, Knies P. Enhancing environmental quality in agricultural systems. Acta Hortic 2003; 609:277–283.
8. UNESCO World Water Assessment Programme. The 3rd United Nations World Water Development Report: water in a changing world. UNESCO publishing; 2009.
9. Jacobsen SE, Jensen CR, Liu F. Improving crop production in the arid Mediterranean climate. Field Crops Res 2012; 128:34–47.
10. FAO. Rome (Italy); International Atomic Energy Agency, Vienna (Austria), WorldCat; 2002, pp. 11-15.
11. Kirda C, Cetin M, Dasgan Y, Topcu S, Kaman H, Ekici B, et al. Yield response of greenhouse-grown tomato to partial root drying and conventional deficit irrigation. Agric Water Manag 2004; 69:191-201.
12. Rahil MA, Qanadillo A. Effects of different irrigation regimes on yield and water use efficiency of cucumber crop. Agric Water Manag 2015; 148:10–15.
13. Steel RGD, Torrie JH. Principles and Procedures of Statistics. A Biometrical Approach. 2. ed. New York: McGraw–Hill; 1980.
14. Arshad, I. Effect of water stress on the growth and yield of greenhouse cucumber (*Cucumis sativus* L.). PSM Biol Res 2017; 2:63-67.
15. El-Mageed, Semida WM, Taha RT, Rady MM. Effect of summer fall deficit irrigation on morpho-physiological, anatomical responses, fruit yield, and water use efficiency of cucumber under salt affected soil. Sci Hortic 2018; 237:148-155.
16. Sankar V, Lawande KE, Tripathy PC. Effect of micro irrigation on growth, yield and water-use-efficiency of onion (*Allium cepa*) under western Maharashtra conditions. Indian J Agric Sci 2008; 78:584-588.
17. Ünlü M, Kanber R, Koç DL, Tekin S, Kapur B. Effects of deficit irrigation on yield & yield components of drip irrigated cotton in Mediterranean environment. Agric Water Manag 2011; 98:597-605.
18. Hashem FA, Medany MA, Abd El-Moniem EM, Abdallah MMF. Influence of greenhouse cover on potential evapotranspiration and cucumber water requirements. Annals Agriculture Science: 2011; 56: 49-55.
19. Pattanaik SK, Sahu NN, Pradhan PC, Mohanty MK. Response of banana to drip irrigation under different irrigation designs. J Agric Eng 2003; 40:29-34.
20. Patanè C, Cosentino SL. Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. Agric Water Manag 2009; 97:131–138.
21. Kirda C, Kanber R, Moutonnet P, Hera C, Nielsen DR. Water, no longer a plentiful resource, should be used sparingly in irrigated agriculture; 1999.
22. FAO. Guidelines for Designing and Evaluating Surface Irrigation Systems. Irrigation and Drainage paper No. 45. Rome, Italy: FAO: 1989.
23. Amandeep K, Brar AS. Influence of mulching and irrigation scheduling on productivity and water use of turmeric (*Curcuma longa* L.) in north-western India. Irrig Sci 2016; 34:261–269.
24. Savva AP, Frenken K. Crop water requirements and irrigation scheduling. Irrigation manual module 4, Harare; 2002.
25. Zhang HX, Chi D C, Wang Q, Fang J, Fang XY. Yield and quality response of cucumber to irrigation and nitrogen fertilization under subsurface drip irrigation in the solar greenhouse. Agric Sci China 2011; 10:921-930.
26. Houshang G, Mohammad A, Parandyna I, RezvanV. An evaluation and comparison of drip and conventional furrow irrigation methods on maize. Arch Agron Soil Sci 2013; 59:733–751.